VM Management for Green Data Centres with the OpenNebula Virtual Infrastructure Engine

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Objectives

VM Management for Green Data Centres with OpenNebula

- **Workshop:**
  - Development of a *reference model for the management of energy efficiency* in virtualized distributed environments

- **Presentation:**
  - Introduce the **OpenNebula Virtual Infrastructure Engine**
  - Propose a *model for the dynamic management of VMs in distributed infrastructures*
  - Describe a first prototype of scheduler for *distribution of VM workloads based on energy requirements*
What is OpenNebula?

VM Management for Green Data Centres with OpenNebula

Extending the Benefits of Virtualization to Clusters

• Dynamic deployment and re-placement of virtual machines on a pool of physical resources

• Transform a rigid distributed physical infrastructure into a flexible and agile virtual infrastructure

Private Cloud: Virtualization of cluster or data-center for internal users

Backend of Public Cloud: Internal management of the infrastructure

Cloud Interoperation: On-demand access to public clouds
Virtual Machine Management Model

VM Management for Green Data Centres with OpenNebula

Service as Management Entity

- Service structure
  - Service components run in VMs
  - Inter-connection relationship
  - Placement constraints
- The VM Manager is service agnostic
- Provide infrastructure context

Distributed VM Management Model

The three pillars of a Distributed VM Manager
Benefits

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System Manager

- **Centralized management** of VM workload and distributed infrastructures
- Support for **VM placement policies**: balance of workload, server consolidation...
- **Dynamic resizing** of the infrastructure
- **Dynamic partition** and isolation of clusters
- Support for **heterogeneous workload**
- **Dynamic scaling** of private infrastructure to meet fluctuating demands

Service Manager

- **On-demand provision** of virtual machines

System Integrators

- **Open and flexible** architecture and interfaces, open source software
- **Integration** with any component in the virtualization/cloud ecosystem, such as cloud providers, hypervisors, cloud-like interfaces, virtual image managers, service managers, schedulers...
# Features

**VM Management for Green Data Centres with OpenNebula**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User Interface</strong></td>
<td>• Unix-like CLI to manage VM life-cycle and physical boxes</td>
</tr>
<tr>
<td></td>
<td>• XML-RPC API and libvirt interface</td>
</tr>
<tr>
<td><strong>Scheduler</strong></td>
<td>• Requirement/rank matchmaker</td>
</tr>
<tr>
<td></td>
<td>• Generic framework to build any scheduler</td>
</tr>
<tr>
<td><strong>Virtualization Management</strong></td>
<td>• Xen, KVM and libvirt connectors</td>
</tr>
<tr>
<td></td>
<td>• Amazon EC2</td>
</tr>
<tr>
<td><strong>Image Management</strong></td>
<td>• General mechanisms to transfer and clone VM images</td>
</tr>
<tr>
<td><strong>Network Management</strong></td>
<td>• Definition of virtual networks to interconnect VMs</td>
</tr>
<tr>
<td><strong>Fault Tolerance</strong></td>
<td>• Persistent database backend to store host and VM information</td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td>• Tested in the management of hundreds of VMs</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>• Installation on a UNIX cluster front-end without requiring new services in the remote resources</td>
</tr>
<tr>
<td></td>
<td>• Distributed in Ubuntu 9.04 (Jaunty Jackalope), due to be released in April 2009</td>
</tr>
</tbody>
</table>
Open and Flexible Architecture

VM Management for Green Data Centres with OpenNebula

- Scheduler
- CLI
- libvirt

OpenNebula API

XML-RPC

OpenNebula core

- Host, Net & VM Pools
- Information Manager
- Network Manager
- Image Manager
- VM Manager

sqlite

Persistent Database

Access Drivers

- XEN
- KVM
- EC2
- libvirt
Use Cases

VM Management for Green Data Centres with OpenNebula

On-demand Scaling of Computing Clusters

- Elastic execution of a **SGE computing cluster**
- Dynamic growth of the number of worker nodes to meet demands using EC2
- Private network with NIS and NFS
- EC2 worker nodes connect via VPN

On-demand Scaling of Web Servers

- Elastic execution of the **NGinx web server**
- The capacity of the elastic web application can be dynamically increased or decreased by adding or removing NGinx instances
Ecosystem

VM Management for Green Data Centres with OpenNebula

Schedulers

- **Haizea**: Open-source VM-based lease management architecture (allows AR of capacity).

![Haizea Diagram]

Lease requests

"I need 10 nodes, each with 2 CPUs, 4GB of memory, from 2pm to 4pm"

Interfaces

- **Libvirt**: Provides an abstraction of a whole cluster of resources as one host, hiding specific hypervisor details.
- **Nimbus**: Can be used as a WSRF or EC2 front-end.

Plug-Ins

- **ElasticHosts**: Enables the dynamically increase capacity of your virtualized infrastructure to meet fluctuating peak demands using a cloud provider.
Model for VM Management in Distributed Infrastructures

VM Management for Green Data Centres with OpenNebula

Energy Policy Enactment

Energy Policy Definition

Virtual Infrastructure Manager

Centralized management of VMs and resources
- VM life-cycle management
- VM image management
- Virtual network management
- Fault tolerance

Automation of VM placement:
- Balance of workload
- Server consolidation
- Placement constraints and affinity
- Advance reservation of capacity
- SLA commitment

VM Manager
Physical Box

VM Manager
Physical Box

VM Manager
Physical Box

VM Manager
Physical Box

VM

VM

VM

VM

Scheduler

Monitoring & Accounting

Controlling (CLI/API)
Monitoring and Accounting

VM Management for Green Data Centres with OpenNebula

VM Life-cycle and Monitoring

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>VM identifier</td>
</tr>
<tr>
<td>NAME</td>
<td>Name of the VM</td>
</tr>
<tr>
<td>STAT</td>
<td>Status</td>
</tr>
<tr>
<td>CPU</td>
<td>CPU percentage used by the VM</td>
</tr>
<tr>
<td>MEM</td>
<td>Memory used by the VM</td>
</tr>
<tr>
<td>HOSTNAME</td>
<td>Host where the VM is running</td>
</tr>
<tr>
<td>TIME</td>
<td>Time since submission</td>
</tr>
</tbody>
</table>
Monitoring and Accounting

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Resource Monitoring

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HID</td>
<td>Host ID</td>
</tr>
<tr>
<td>NAME</td>
<td>Host name</td>
</tr>
<tr>
<td>RVM</td>
<td>Number of running VMs</td>
</tr>
<tr>
<td>TCPU</td>
<td>Total CPU (percentage)</td>
</tr>
<tr>
<td>FCPU</td>
<td>Free CPU (percentage)</td>
</tr>
<tr>
<td>ACPU</td>
<td>Available CPU (not allocated by VMs)</td>
</tr>
<tr>
<td>TMEM</td>
<td>Total memory</td>
</tr>
<tr>
<td>FMEM</td>
<td>Free memory</td>
</tr>
<tr>
<td>STAT</td>
<td>Host status</td>
</tr>
</tbody>
</table>

Flexible Architecture

- Easy addition of new VM and resource metrics (energy efficiency metrics)
- Experimenting with Advanced Configuration and Power Interface (ACPI) for power monitoring

Accounting

- Statistics of host usage, VM image transfer times....
Controlling

VM Management for Green Data Centres with OpenNebula

VM Controlling

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>create</td>
<td>Submits a new virtual machine, adding it to the VM pool</td>
</tr>
<tr>
<td>deploy</td>
<td>Starts a previously submitted VM on a specific host</td>
</tr>
<tr>
<td>shutdown</td>
<td>Shutdown an already deployed VM</td>
</tr>
<tr>
<td>livemigrate</td>
<td>Migrates a running VM to another host without downtime</td>
</tr>
<tr>
<td>migrate</td>
<td>Saves a running VM and starts it again in the specified host</td>
</tr>
<tr>
<td>stop</td>
<td>Stops a running VM</td>
</tr>
<tr>
<td>Release/hold</td>
<td>Releases/hold a VM from/to hold state</td>
</tr>
<tr>
<td>Suspend/resume</td>
<td>Saves/resume a VM</td>
</tr>
</tbody>
</table>

Resource Controlling

<table>
<thead>
<tr>
<th>Action</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Create/delete</td>
<td>Adds/removes a machine to/from the pool</td>
</tr>
<tr>
<td>Enable/disable</td>
<td>Enables/disables host</td>
</tr>
</tbody>
</table>
Resource Schedulers

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Requirement/rank Matchmaker (default)

• First placement of pending VMs to resources meeting the “requirements” and sorted using a “rank“ expression

Haizea Lease Manager (University of Chicago)

• Advance reservation of capacity and queuing of best effort requests

RESERVOIR Policy Engine (IBM Haifa/Elsa Datamat)

• Policy-driven probabilistic admission control and dynamic placement optimization to satisfy site level management policies

VM Consolidation Scheduler

• Periodic re-placement of VMs for server consolidation and suspension/resume of physical resources

• Experimental for supporting research on distribution of VM workload based on energy requirements and policies
VM Consolidation Scheduler

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Control Flow

- Complements the work done by the requirement/rank matchmaker for first deployment of VMs in pending state

```
Enable host

VM pending?

Yes

Disable free hosts

Packing algorithm

Period: 20 minutes

Consolidation?

Yes

Migration

Physical Resource Management

Virtual Machine Management
```
VM Consolidation Scheduler

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A Simple Example

1) Initial situation

2) **Exec. 1**: Packing algorithm in the VM
   Consolidation Scheduler requests a migration

3) **Exec. 2**: VM Consolidation Scheduler
   “disables” a physical resource

4) **Exec. 3**: VM consolidation scheduler
   “enables” a physical resource because
   there are pending VMs

5) **Exec. 3**: VM consolidation scheduler
   “enables” a physical resource because
   there are pending VMs

6) The requirement/rank matchmaker schedules
   the pending VMs
VM Consolidation Scheduler

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A Simple Example
VM Consolidation Scheduler

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Future Work: Energy Policy-driven Scheduler

Monitoring

• Power and heat metrics (ACPI specification)
• Past history (trends) of resources and workload

Enactment of policies

• Management of power-state of the resources (ACPI specification)

Policies

• Support for “generic energy policies”
• Selection of the VMs to migrate and the target host for migration
• …
Conclusions
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• **Workshop:**
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• **Presentation:**
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THANK YOU FOR YOUR ATTENTION!!!
More info, downloads, mailing lists at www.OpenNebula.org

Real demo at booth number 4

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